

Applying Intelligent Systems Technology to Extract and Understand Radio Imaging Data: An Application to Radio Plasma Imager Data from the *IMAGE* Mission

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Abstract

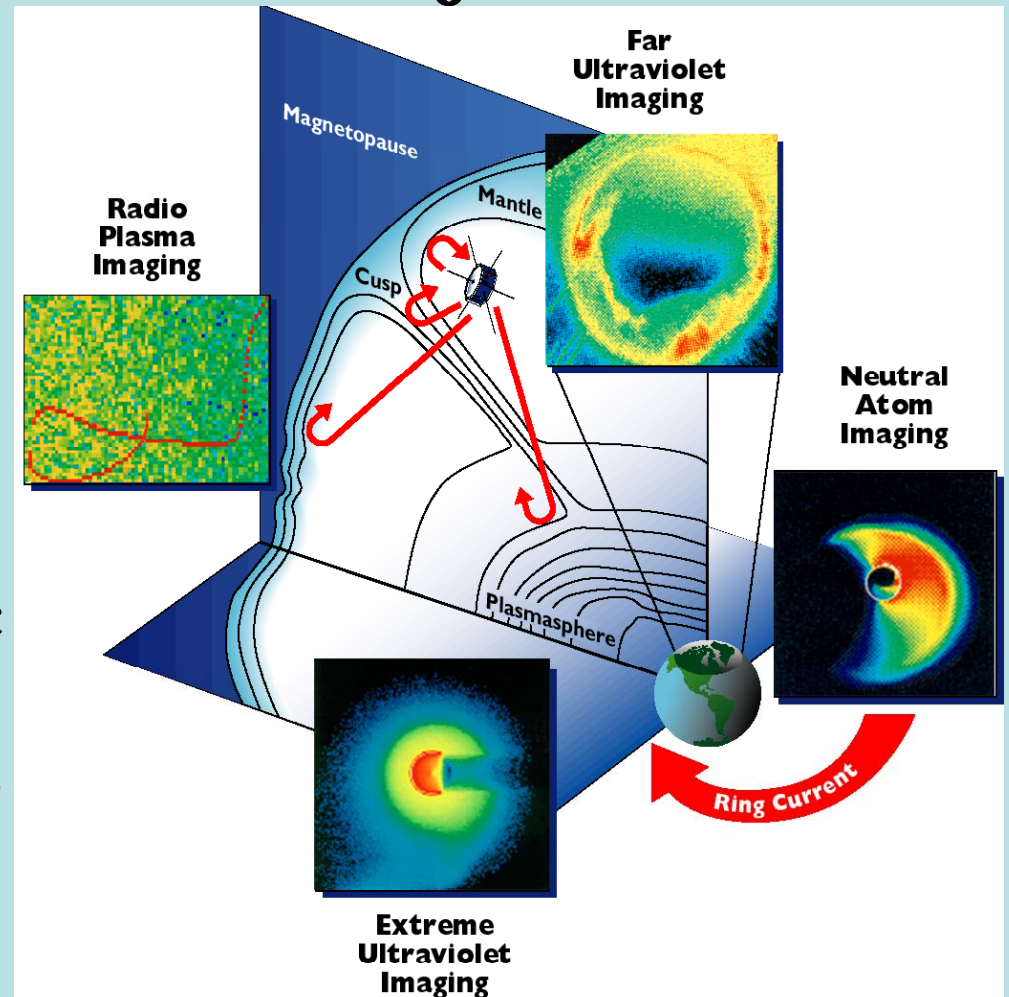
Our objective is to develop the capability to *automatically process* radio imaging data to identify and extract magnetospheric radio-echo and natural plasma-wave signals recorded by the Radio Plasma Imager (RPI) on the *NASA IMAGE* satellite. Such a capability is highly desirable by the space science research community to efficiently glean the signatures of interest, for further study and analysis, from a large number (millions) of radio imaging records. The capability, if implemented in spacecraft instrument flight software, will also allow automatic control of spacecraft instrument operations based on real-time spacecraft observations. As an Intelligent-System Technology (IST) infusion project, we will endeavor to adapt IST currently under development or implementation into our discipline data environment to investigate how such a desired capability may be developed.

Since the beginning of the project in December 2002 we have identified IST projects that can potentially be adapted for our applications. They have been prioritized according to their readiness for successful infusion. A partnership has been formed with one technology partner (Dr. James C. Tilton, NASA Goddard Space Flight Center) whose hierarchical image segmentation (*HSEG*) technique has demonstrated a high potential of applicability to our data. We describe in this poster the progress made to date.

IMAGE Science Objectives

The IMAGE spacecraft (launched on March 25, 2000) uses only *remote imaging techniques* to:

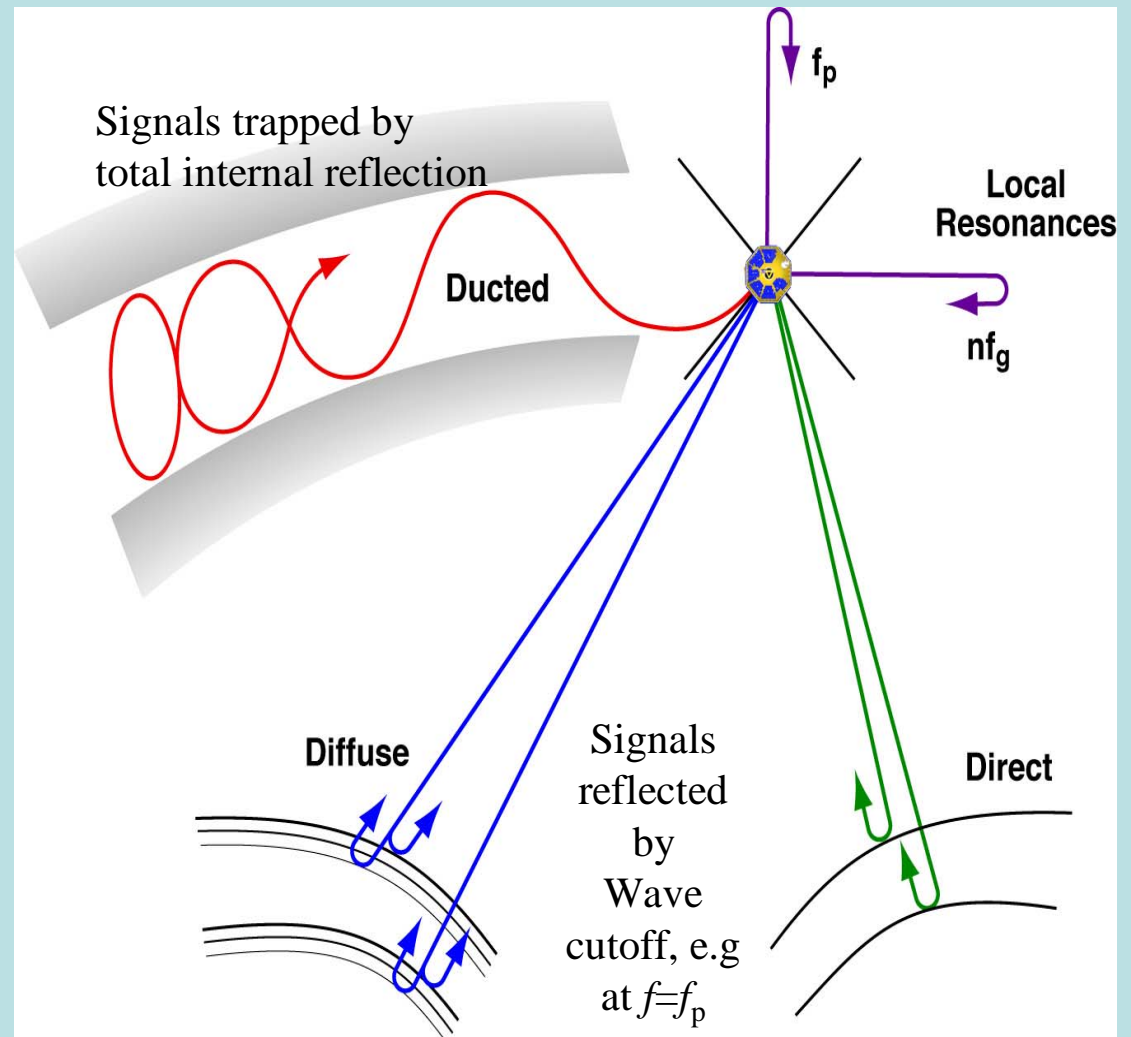
- 1) **Determine** the global-scale magnetospheric structure
- 2) **Determine** magnetospheric dynamical responses to changes in the solar wind (*i.e., Sun-Earth Connection; space weather*)
- 3) **Elucidate** sources and losses of magnetospheric plasmas



“Seeing the Invisible”

Radio Plasma Imager (RPI): A Space RADAR

- RPI transmits coded EM waves in frequency range 3 kHz – 3 MHz and receives resulting echoes
- At each frequency, the RPI measurements of interest are:
 - Echo amplitude
 - Echo time delay (which yields the distance, or range, to the target)
 - Wave polarization (ordinary or extraordinary)
- RPI also takes passive observations of natural emissions



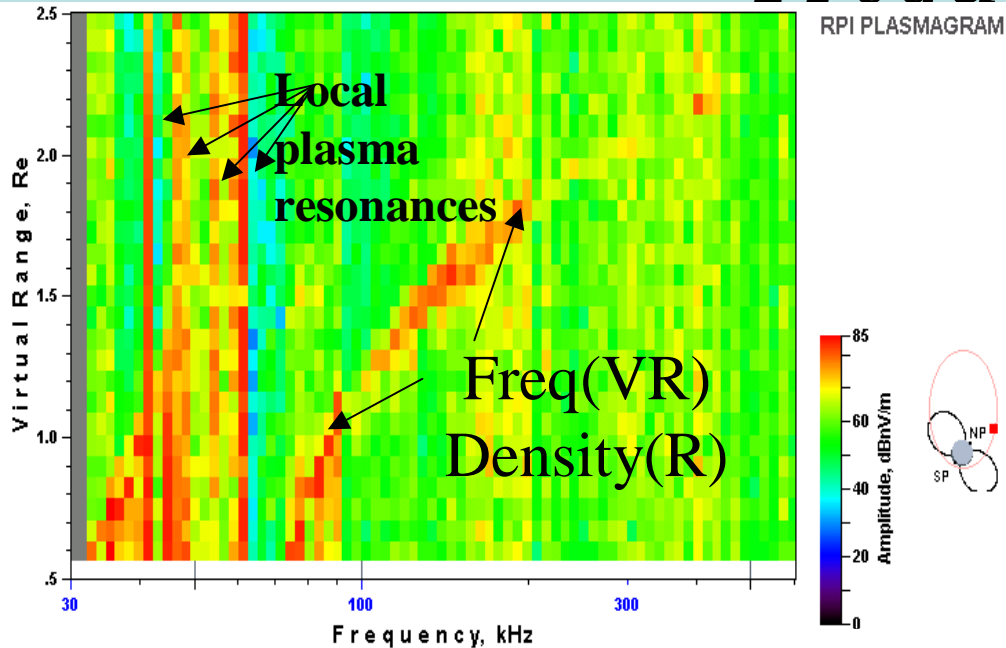
Examples of Observed Echoes



Background
noise removed

Background
noise present

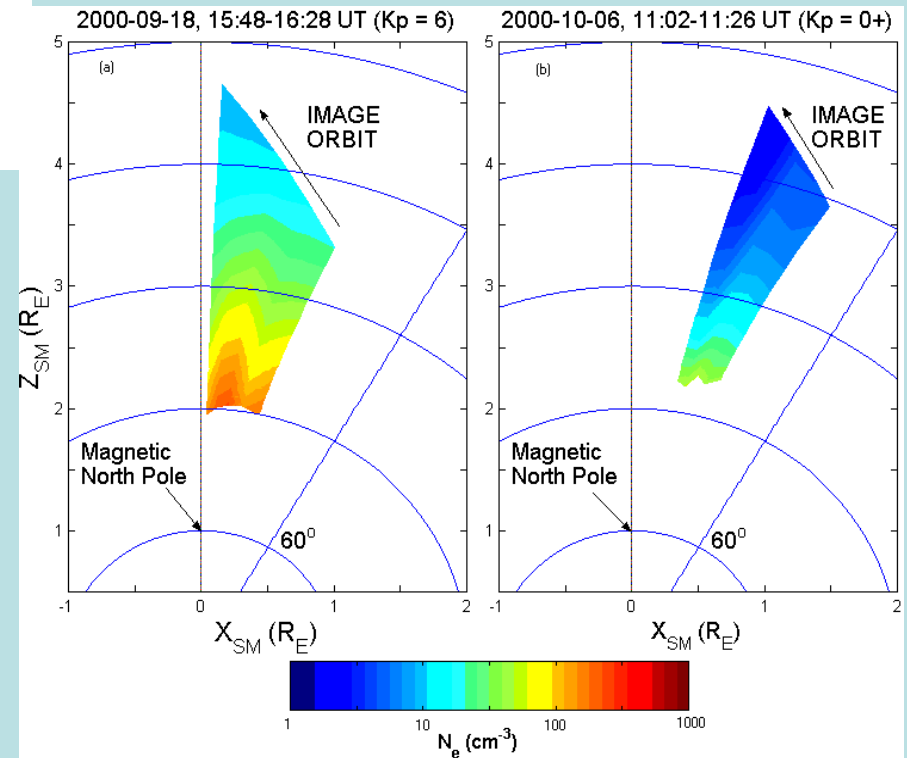
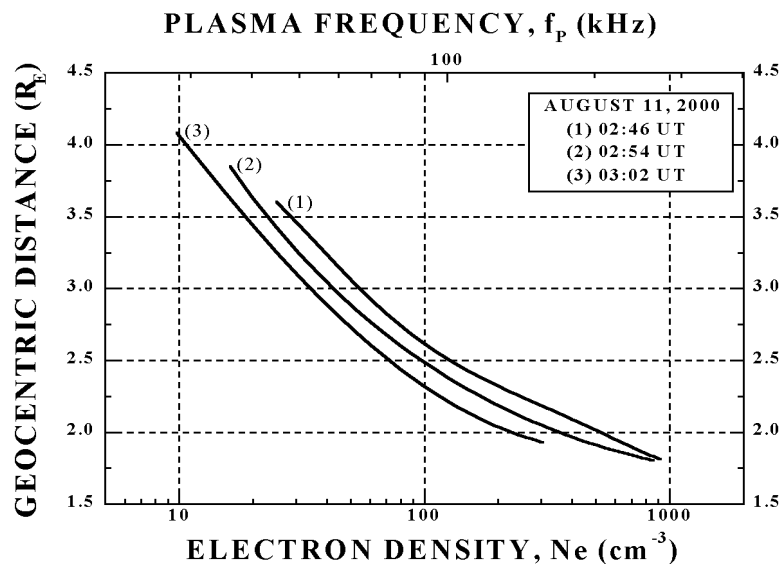
Plasmagram: Virtual Range vs. Frequency



Polar Cap Density Distributions
Constructed from Consecutive Soundings

Active
condition

Quiet
condition



Guided Echoes Provide Only Means to Observe Density Distribution Along Field lines



RPI Plasma Wave (Passive) Observations

**Unidentified
emission**

**Auroral
kilometric
Radiation**

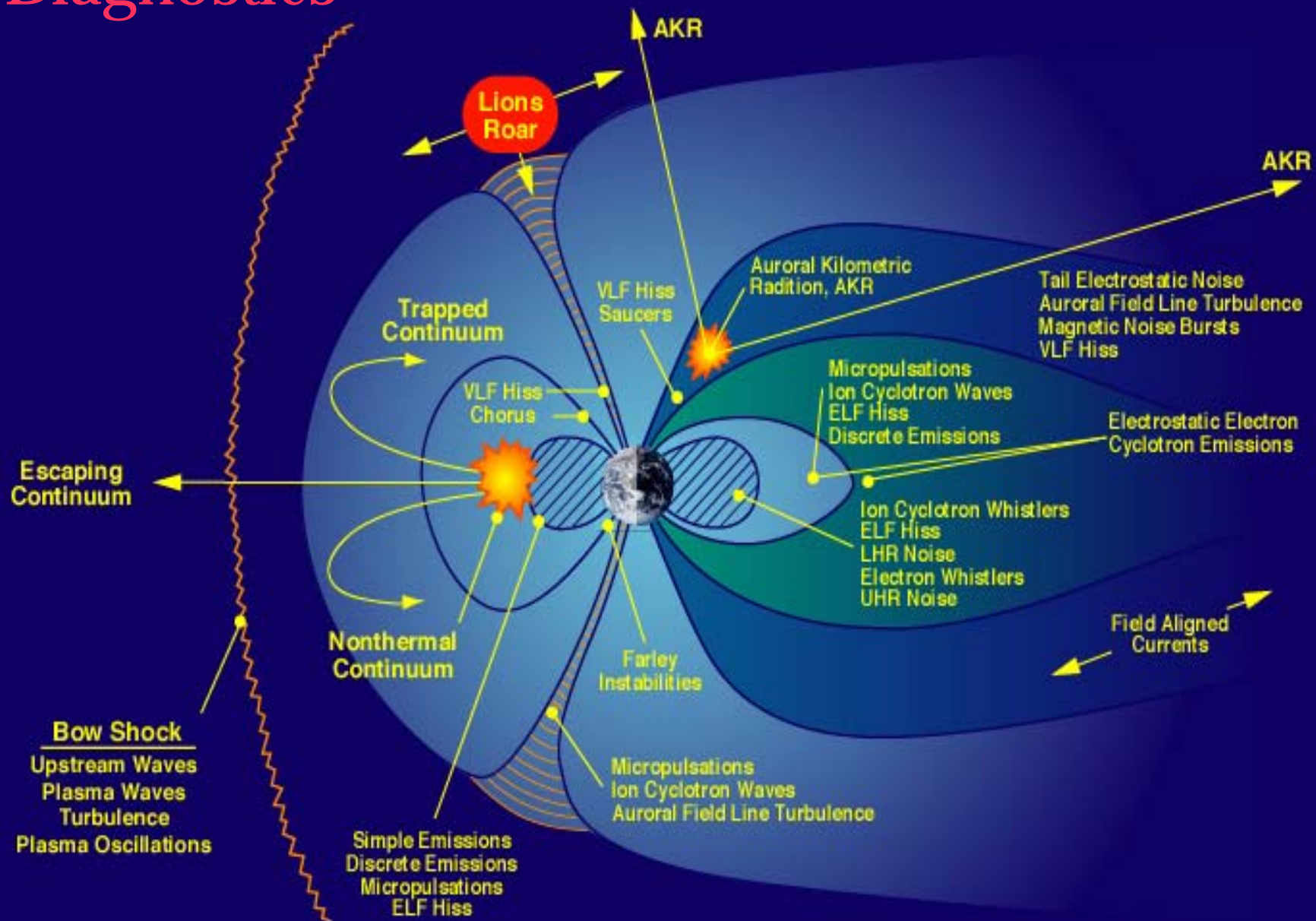
**Solar type III
radio burst**

QuickTime™ and a
PNG decompressor
are needed to see this picture.

**High density
plasmasphere**

Plasmaspheric hiss

Plasma Waves as Magnetospheric Diagnostics



Existing *RPI* Feature Identification Software,
CORPRAL: Cognitive Online *RPI* Plasmagram
Ranking ALgorithm (see poster by Galkin et al)

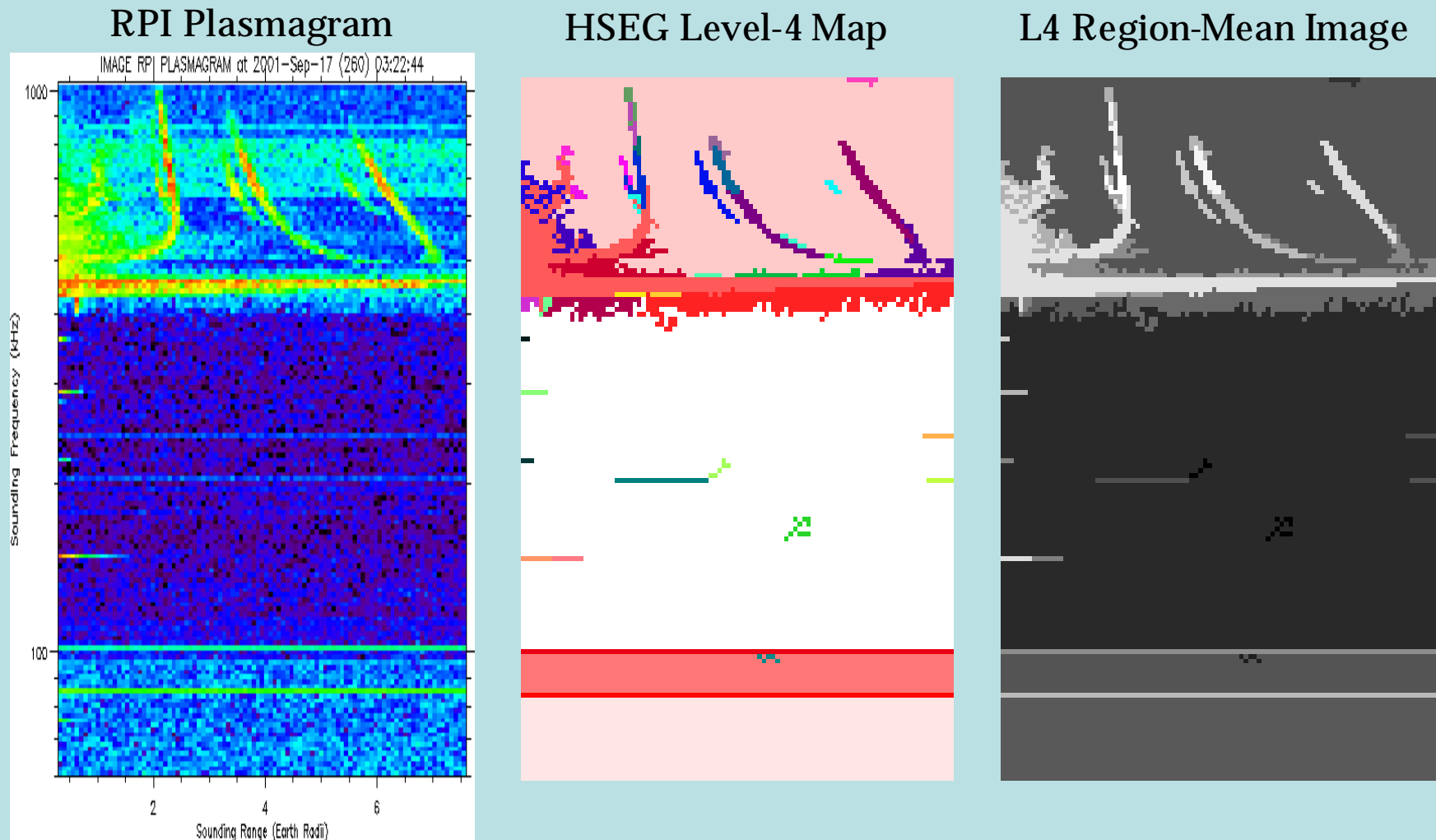
- Still under development, works moderately well when used by domain-science experts
- Not yet sufficiently reliable for on-board automatic data processing
- We propose to investigate how we may improve *CORPRAL* reliability and performance by infusing Intelligent Systems Technology

Hierarchical Image Segmentation: Potential IS Technology for Infusion (see IDU Talk by J. Tilton)

A set of image segmentations that

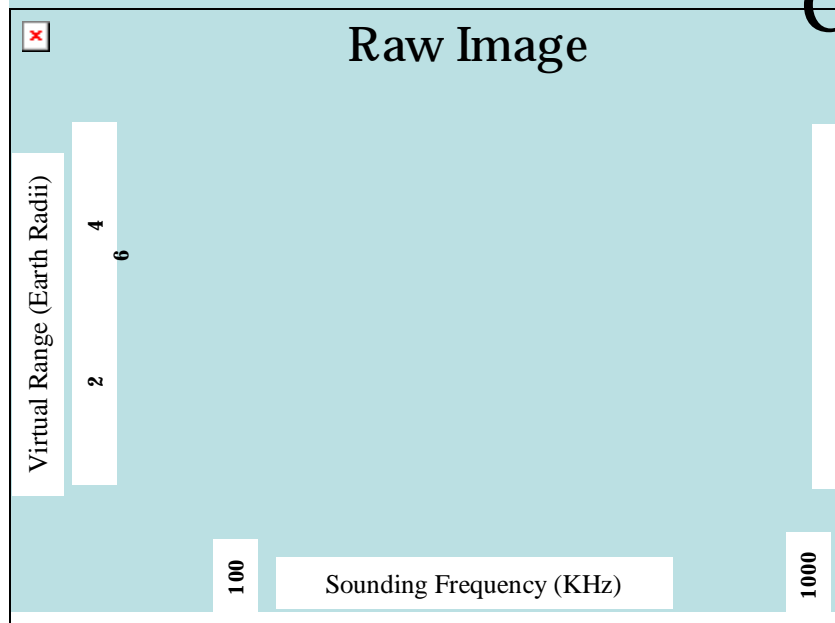
- i. consists of segmentations at different levels of detail in which
- ii. the coarser segmentations can be produced from simple merges of regions from the finer segmentations, and
- iii. the region boundaries are maintained throughout at the full image spatial resolution.

Application of HSEG Processing to RPI Plasmagram



Example of an RPI plasmagram (left panel) in which the echo traces can be clearly identified and extracted by HSEG processing (center panel). Right panel shows the plot of “region means” from which uniform “background” can be defined and subtracted.

RFI Plasmagram Processed with HSEG using 12 Nearest Neighbor Connectivity and No Spectral Clustering



QuickTime™ and a PNG decompressor are needed to see this picture.

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An arbitrarily pseudo-colored rendition of the raw input data

- Segmentation result selected from a hierarchy of 18 hierarchical levels found

Color	Boundary/Total Area		Hierarchy Level	
Yellow	1.0	0.906	5	6
White	1.0	0.849	8	9
Light Orange	0.906	0.849	8	9
Brown	0.33427	0.33412	8	9
Blue	1.0	0.869	9	10
Light Pink	0.931	0.249	10	11
Turquoise	1.0	0.108	14	15
Green	1.0	0.094	15	16
Red	1.0	0.055	16	17

RPI Data Processed Using 24 Nearest Neighbor Connectivity & Spectral Clustering weight = 1.0



QuickTime™ and a
PNG decompressor
are needed to see this picture.

An arbitrarily pseudo-colored rendition
of the raw input data

QuickTime™ and a
PNG decompressor
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PNG decompressor
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- Above-left panel shows
 - Segmentation result selected from a hierarchy of 25 hierarchical levels
 - The scattered plasmasphere feature doesn't come through very well. The blue area captures it somewhat, but it is mixed with other features at the lower and higher frequencies
- Above-right panel results from
 - Masking out the data where the columns were > 50% blue or red
 - 18 hierarchical levels were then found.
 - The gray area is the masked area
- Repeated applications of masking and HSEG may help clear up “noise bands” and extract the scattered echo feature

Conclusions

- From results of test applications, the Hierarchical Segmentation (HSEG) Technique shows high potential for being adapted into the RPI data processing/analysis infrastructure to extract features from RPI data.
- Process of technology infusion is in progress.
- Incorporation of domain science knowledge will be important for both CORPRAL and HSEG to work successfully.

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Goal: Develop techniques to allow automated onboard commanding of spacecraft instruments based on real-time radio observations.

Objectives: To use IS technology to automate the extraction of real magnetospheric signals in the presence of background natural emissions from the Radio Plasma Imager (RPI) data on the IMAGE mission and to develop new decisions based on this analysis.

Key Innovations:

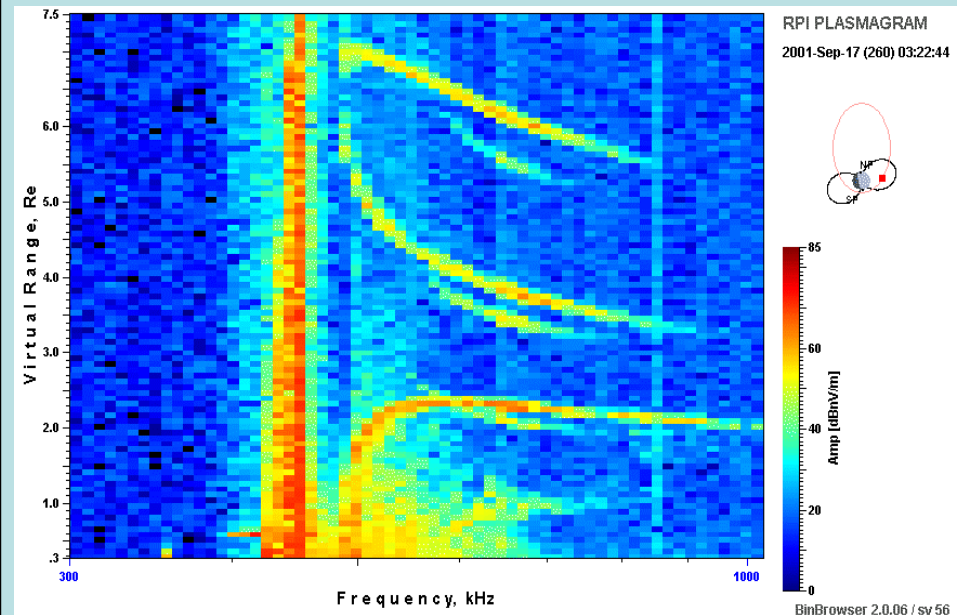
- Applying hierarchical segmentation (HSEG) technique (IS technology) to preprocess RPI images
- Combine IS technology with CORPRAL, the existing RPI feature identification software, to extract radio signals for analysis

NASA Relevance:

- Enable effective analysis of space-based active and passive radio wave observations.
- Enable automated commanding of spacecraft instruments based on real-time radio observations.

Accomplishments to date:

- Reviewed and identified existing IS technology (HSEG/RHSEG by J. Tilton, GSFC) for infusion
- Testing of HSEG applications to RPI data in progress



Schedule:

- Dec 02 - Nov 03
 - Review key existing IS projects and identify the pertinent IS technology to be inserted (completed)
 - Adapt HSEG to analyze IMAGE RPI Data
- Dec 03 - Nov 04
 - Adapting HSEG to analyze IMAGE RPI Data (in progress)
 - Continue CORPRAL Development
 - Capture and incorporate domain expert knowledge
- Dec 04 - Nov 05
 - Develop plan for flight software
 - Develop and test prototype flight software using the RPI engineering unit at the University of Massachusetts.